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TERMINAL-AREA STOL OPERATING SYSTEMS EXPERIMENTS PROGRAM

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INTRODUCTION

As a result of various studies, it appears that the STOL aircraft can supply a high-speed short-haul transportation system that can operate safely into small city centers and suburban facilities. However, detailed performance data from integrated systems studies are needed to provide adequate information for a sound go-ahead decision. To meet this need, a joint Department of Transportation and National Aeronautics and Space Administration (DOT/NASA) operating systems experiments program has been initiated. This effort is focused on developing information which will aid in the choice by the U.S. Government and industry of system concepts, design criteria, operating procedures for STOL aircraft and STOLports, STOL landing guidance systems, air traffic control systems, and airborne avionics and flight control systems. Ames has developed a terminal-area STOL operating systems experiments program which is a part of the joint DOT/NASA effort.

This paper will describe briefly the Ames operating systems experiments program, its objectives, the program approach, the program schedule, typical experiments, the research facilities to be used, and the program status.

In any short-haul transportation system, there may be various levels of system complexity needed to meet traffic density and weather conditions. Simple low cost systems may be sufficient for low-density traffic conditions in good weather whereas more complex and costly automated systems may be economically justifiable in high-density traffic and poor weather.

NOMENCLATURE

C-3A	De Havilland "Buffalo" STOL aircraft
CDI	course deviation indicator
3-D	three dimensional
4-D	four dimensional
DOT	Department of Transportation
L-8630	

EADI electronic attitude director indicator

FAA Federal Aviation Administration

G & N guidance and navigation system

GN & C guidance, navigation, and control

HSI horizontal situation indicator

ILS instrument landing system

MFD multifunction display

MLS microwave landing system

MLS G/S microwave landing system glide slope

MLS LOC & DME microwave landing system localizer and distance measuring
equipment

MODILS modular instrument landing system

NASA National Aeronautics and Space Administration

STOL short take-off and landing

STOLAND research STOL avionics system

TACAN tactical area navigation

VOR/DME very high frequency omnidirectional range/distance measuring equipment

OBJECTIVES

The overall objective of the Ames operating systems experiments program is to provide information to aid the choice of STOL terminal area GN & C systems and define operational procedures. This information will consist of system performance data as a function of the experimental variables. These variables are system complexity (for

example, raw data, flight director, standard autopilot, fully automatic flight); pilot displays and controls, operational constraints (for example, trajectories); ground navigation aids (VOR/DME, MLS, and TACAN), GN & C concepts (for example, 3-D and 4-D guidance, navigation filter techniques, etc.); and onboard sensors (for example, air data, inertial: gimbal compared with strapdown).

The Ames experiments program consists of three phases: analysis, simulation, and flight test. An advanced avionics system will be installed in two typical STOL vehicles to obtain the desired performance data in flight systems. This information will be used to establish STOL system design criteria.

PROGRAM APPROACH

The major steps to obtaining the required information are illustrated in figure 1. The first step is the definition of the experiment elements. This is a brief but intensive study based on the application and extrapolation of current knowledge and experience to define potential experiments and the number of variables possible in the flight experiments program. During this brief study, experiments with similar requirements can be identified and combined and gaps in the experiment program are defined.

From this first step comes a reasonably detailed definition of the research objectives, a preliminary definition of the experiments program and a set of specifications which are used in design and development of the STOLAND flight test system.

The main research effort consists of analytical studies and piloted closed-loop simulations. Analytical studies are carried out in-house and under contract. Piloted simulations are carried out mainly at Ames.

The analysis and simulation phases serve many purposes. In these phases of the program, the GN & C system concepts are developed in detail and system performance data are obtained. Flight experiments are refined and the flight test program is planned in detail. Every effort is made to obtain the bulk of the system performance data during these phases of the program. As a result of this approach, costs associated with flight test are minimized since flight tests are conducted chiefly to verify system performance obtained during the simulation program and to explore problem areas which cannot be adequately explored in the simulation environment.

SCHEDULE

Presented in figure 2 is a schedule for the analysis, simulation, and flight-test phases. The analysis phase has been underway since July 1971, when Sperry Flight Systems was given a contract to investigate STOL navigation, guidance, and control con-

cepts. This phase of the program will be essentially completed in mid-1973. The in-house analysis effort aimed at development of improved 4-D (time-constrained) guidance, improved automatic speed control concepts, and so forth is scheduled to continue through 1977.

The piloted/automatic flight simulations are scheduled for initiation in early 1973. As previously noted, these simulations will be utilized to define, in detail, the flight experiments and to obtain experimental results.

Flight checkout of the STOLAND system will be initiated in the Convair 340 aircraft in early 1973. The flight tests for the STOL aircraft will be initiated in the fourth quarter of 1973.

TYPICAL EXPERIMENTS

The Ames operating systems experiments program is illustrated in figure 3. Shown here is the STOL airborne/ground system configuration, the levels of G & N system automation to be investigated in the flight experiments program, and one of the flight profiles. The onboard system will allow the investigation of all the important levels of automation from a simple manual system without any augmentation to a fully automatic landing system. Time-constrained, steep, curved decelerating approaches, as well as straight-in approaches, will be investigated to obtain data on system performance. Three different ground navigation aids will be used: a microwave landing system (MODILS) provided by the FAA, VOR/DME, and TACAN. It should be emphasized that the experiments program will allow assessment of the relative merits of various levels of system sophistication in terms of system performance, system complexity, safety, and cost.

In figure 4 is illustrated one of two reference flight paths that are being flown on the simulator during system acceptance tests. This trajectory will be flown later in the flight experiments program. It incorporates a series of tasks which will provide data on system performance for many of the guidance and navigation experiments. As an example, 3-D and 4-D area navigations using VOR/DME or TACAN are evaluated for the section of the flight path in which the aircraft is climbing to altitude for the approach. Problems associated with transitioning from VOR/DME or TACAN to MLS will be investigated on passing into the zone of MLS coverage. The application of 360° azimuth MLS antenna operation using a front- and rear-antenna system will be assessed. Evaluations can be made of 3-D and 4-D guidance and navigation using microwave data to establish helical approach paths, effects of winds, definition of decision height windows, definition of touchdown dispersions, pilot acceptance, and the performance of various display systems configurations.

To illustrate the proposed experiments program better, one specific experiment will be discussed in some detail.

In figure 5 is illustrated the segment of the reference flight path to be used in this specific experiment. The objectives of this experiment are to investigate the effects of variations in the radius of curved descending turns, glide-slope angle, and localizer intercept point on system performance and pilot acceptance in the automatic and flight director modes. The performance criteria to be evaluated are the errors in position and velocity along the path and the touchdown dispersion parameters of position, velocity, and aircraft attitudes.

RESEARCH FACILITIES

The flight system STOLAND is illustrated in figure 6. The system is very flexible and is consistent with the requirements of the experiments program.

The major components of the system are a Sperry 1819A general purpose digital computer and a data adapter which interfaces all the navigation aids, displays, controls, and servos with the computer. A detailed description of the STOLAND system may be found in reference 1.

Most of the STOLAND flight hardware and software will be used in the piloted flight simulation. Those functions shown in black in the STOLAND block diagram are not flight hardware and are provided by the airborne hardware simulator. The STOLAND equipment rack is installed in the simulator as shown in figure 7.

The STOLAND displays and controls are installed in the simulator cockpit as shown in figure 8.

The pilot display panel is shown in detail in figure 9. The Sperry electronic attitude director indicator (EADI) and the multifunction display (MFD) occupy the central position of the panel. A standard horizontal situation indicator (HSI) with a course deviation indicator (CDI) is located below the EADI.

The STOLAND mode select panel and MFD control panel are located adjacent to the MFD. The keyboard and status panel, not shown, are located on a pedestal to the right of the pilot.

The main features of the EADI shown here are the aircraft symbol with roll and horizon reference, the ILS window which provides the pilot with information regarding his position with respect to the MLS localizer and glide slope, the runway symbol just to the left of center, and the airspeed, vertical speed, and altitude in numeric form in the three windows at the top of the display.

The main features shown on the MFD are a reference flight path with respect to the runway at the experimental facility and the airplane symbol which is the triangular shape close to the flight path. On the top of the MFD is displayed the altitude on the left, aircraft heading in the center box, and time on the right. The scale displayed on the MFD is the aircraft heading. The details of the remainder of the STOLAND display panel can be obtained from reference 1.

The simulation allows the evaluation of GN & C and display concepts after the appropriate software has been put into the flight computer. As previously noted, the simulation will also be used for flight software validation, refinement of flight experiments, collection of experimental data, investigation of off-nominal flight conditions, and the comparative evaluation of competitive concepts.

PROGRAM STATUS

The status of the operating systems program is now presented. The GN & C operating systems experiments have been defined in some detail. The STOLAND simulator avionics system is operating at Ames Research Center. Acceptance tests of this system are scheduled for completion in November 1972. The STOLAND flight avionics system is scheduled for delivery in November 1972, with acceptance tests scheduled in December 1972. Experiments development and baseline data collection utilizing the STOLAND simulator will be initiated in January 1973. STOLAND avionics system flight checkout and preliminary data collection is scheduled on the Convair 340 aircraft in February 1973. Utilization of manual modes will be emphasized in these tests. Flight data collection utilizing the C-8A STOL and augmentor wing jet STOL aircraft is scheduled in the fourth quarter of 1973.

CONCLUDING REMARKS

A STOL GN & C operating systems experiments program has been defined to provide information for choice of STOL terminal area systems and operational procedures.

This information will allow the U.S. Government and industry to establish systems design criteria and to make trade-off studies of cost, safety, and return on investment as a function of system complexity.

A STOL simulator has been put into operation which utilizes airborne hardware and software. This simulator will be used to develop G & N system concepts, operating system experiments, and to perform other tasks in support of the program. A flight program has been developed to verify GN & C system concept performance which cannot be reliably measured by using analysis and flight simulation procedures. The flight program will

utilize the STOLAND flight avionics system in conjunction with three aircraft, the Convair 340, the C-8A STOL aircraft, and the augmentor wing jet STOL research aircraft.

REFERENCE

1. Hansen, Q. M.; Young, L. S.; Rouse, W. E.; and Osder, S. S.: Development of STOLAND, a Versatile Navigation, Guidance and Control System. AIAA Paper No. 72-789, Aug. 1972.

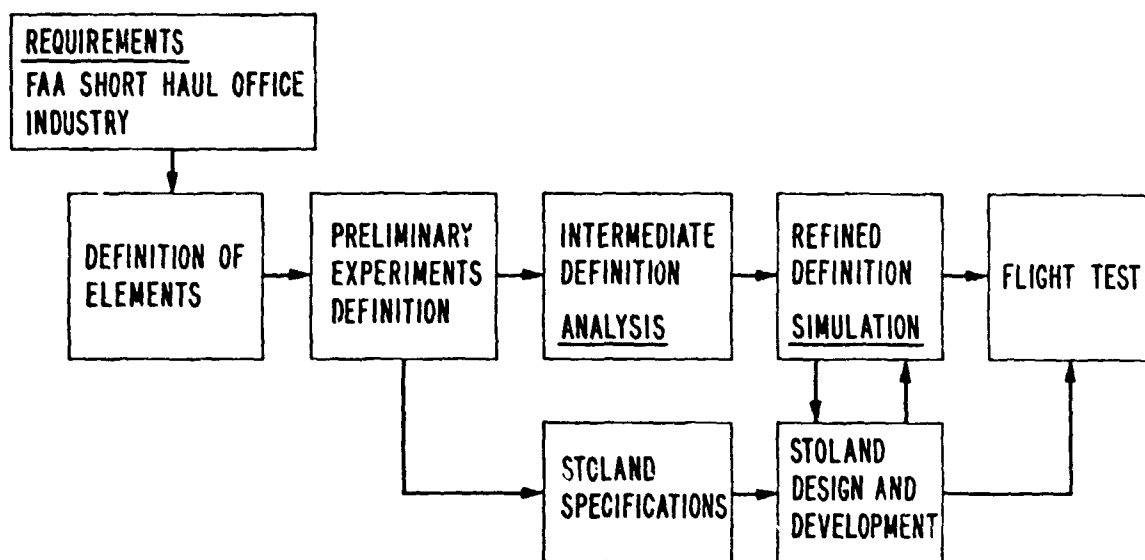


Figure 1.- Experiments approach.

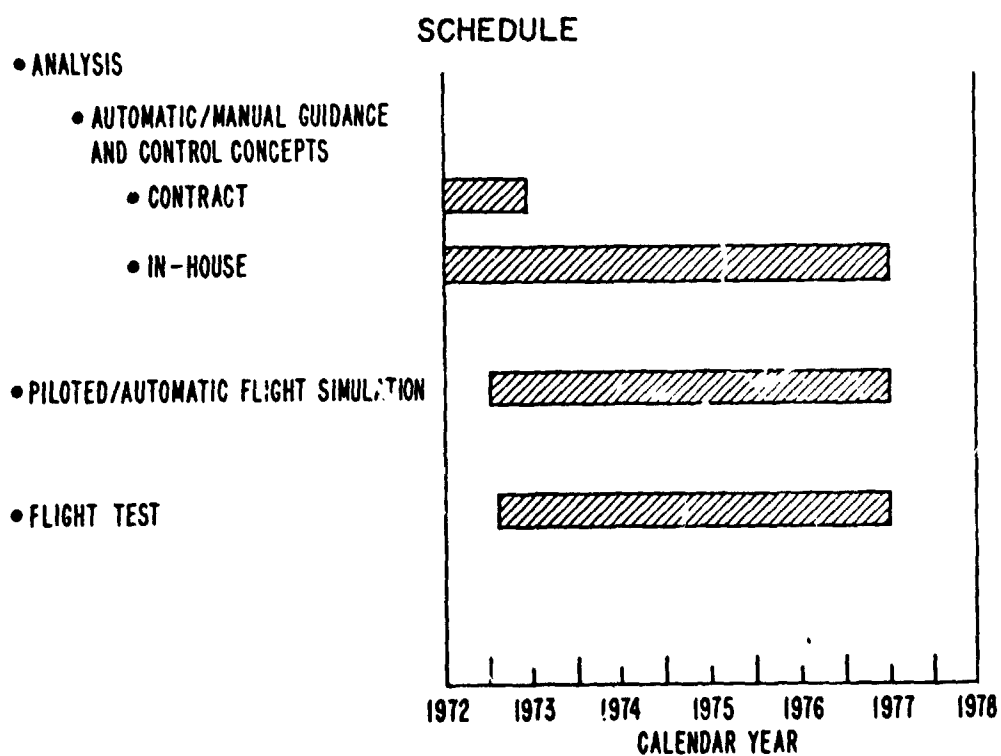


Figure 2.- STOL terminal area guidance, navigation and control operating systems experiments.

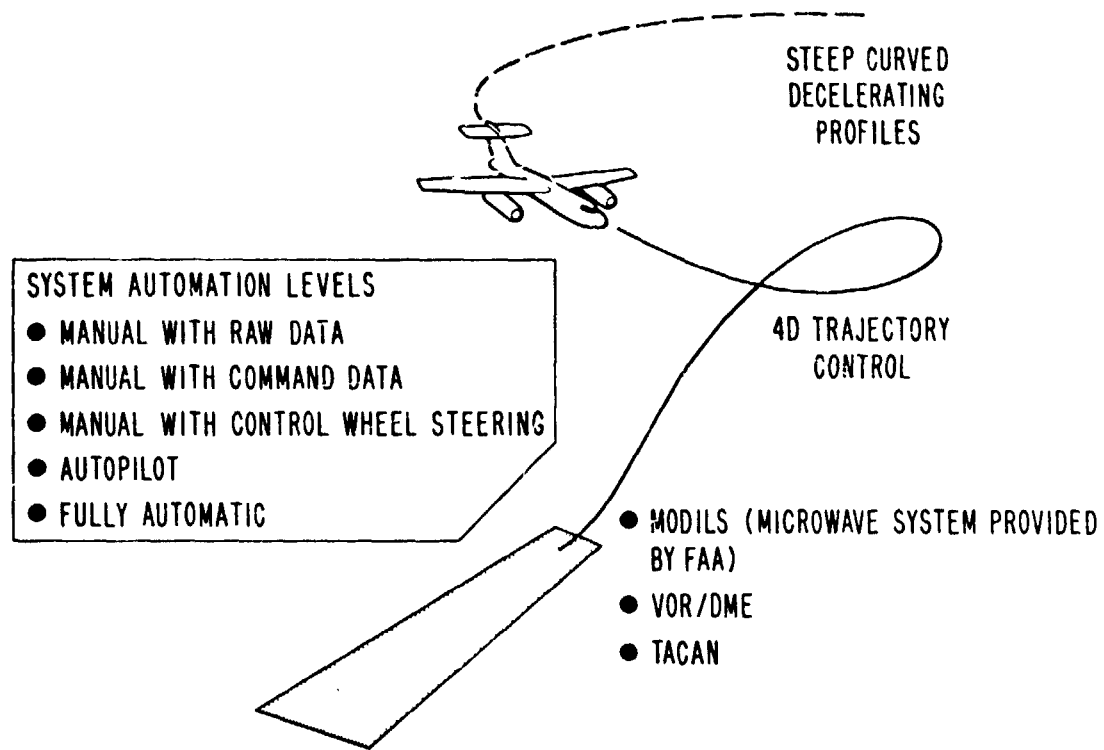


Figure 3.- STOL airborne/ground systems configuration.

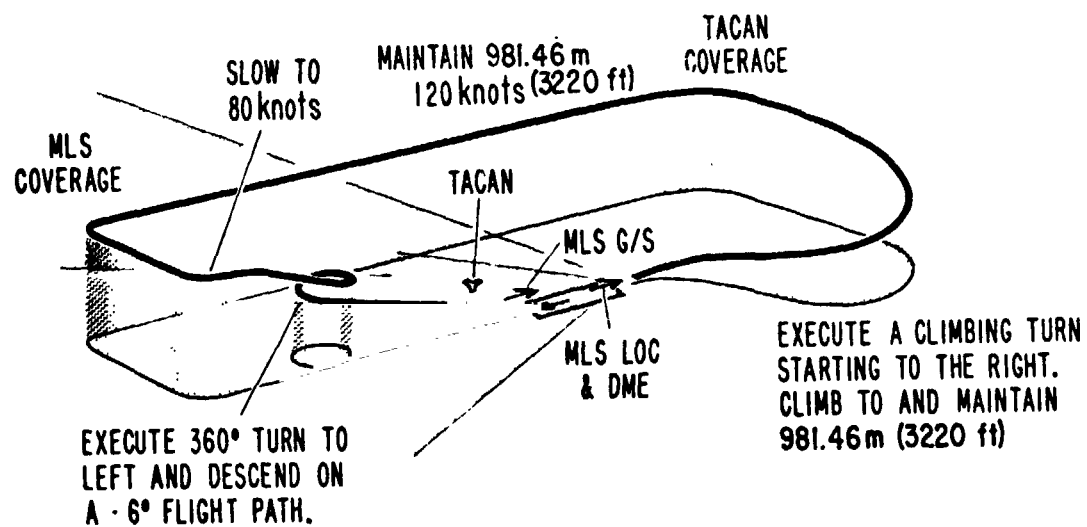
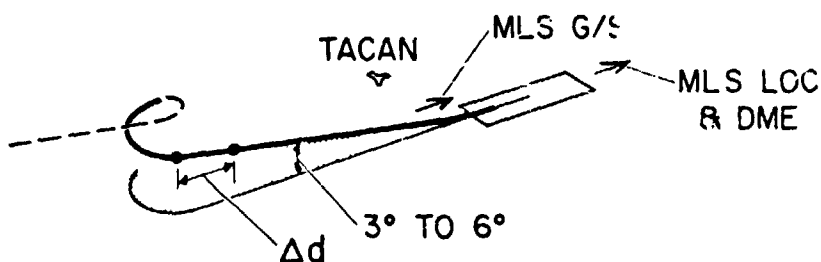


Figure 4.- Typical flight path for GN&C experiments.

● VARIABLES

- RADIUS OF CURVED DESCENDING TURN
- GLIDE SLOPE ANGLE
- LOCALIZER INTERCEPT POINT LOCATION



Δd = DISTANCE REQUIRED TO STABILIZE ON GLIDE SLOPE AND LOCALIZER.

Figure 5.- Segment of flight path for a specific experiment.

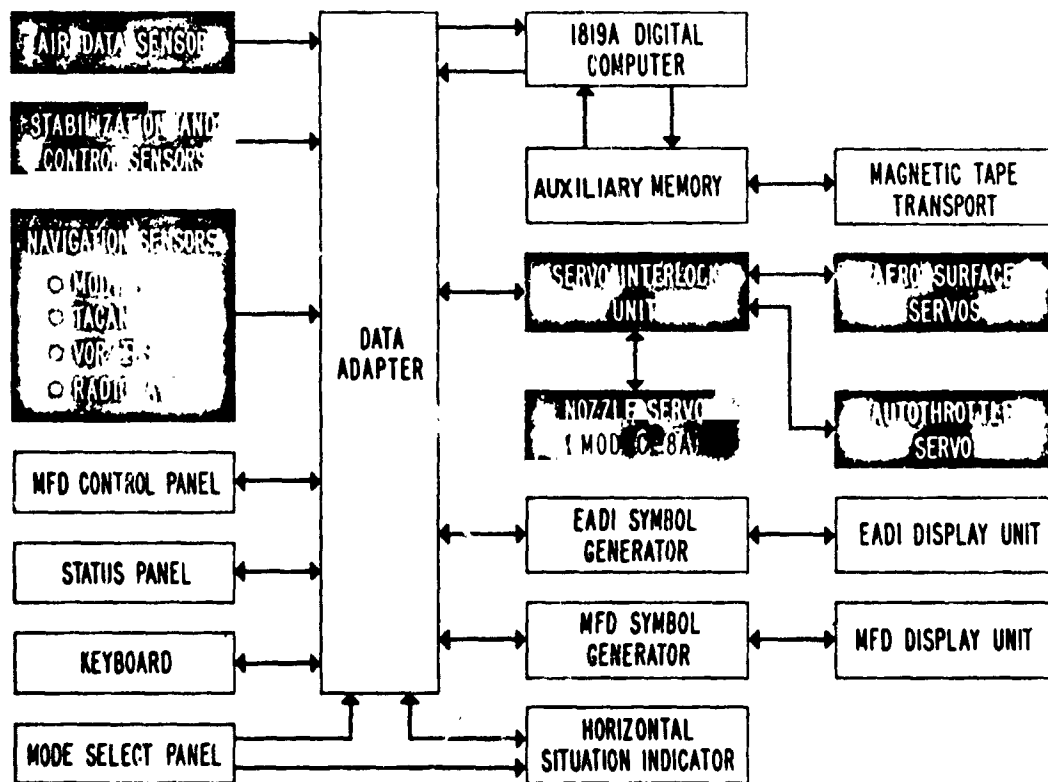


Figure 6.- STOLAND block diagram.



Figure 7.- Simulator STOLAND equipment installation.

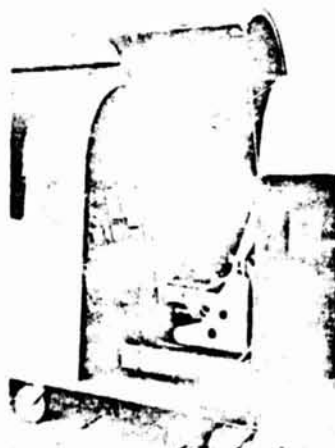


Figure 8.- STOLAND simulation cockpit.

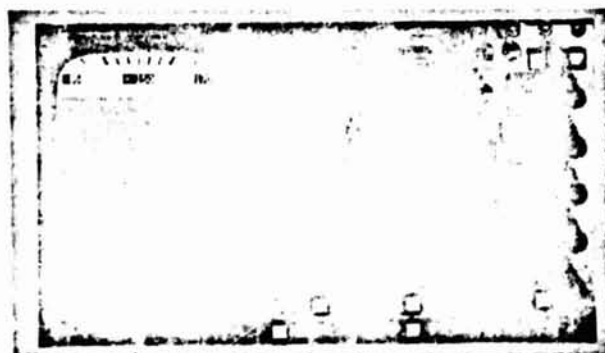


Figure 9.- STOLAND pilot display panel.